Chapter

# Soil Degradation and the Human Condition, Including the Pandemic, Interactions, Causes, Impacts, Control Measures and Likely Future Prospects

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## Abstract

The global spread of soil degradation threatens the sustainability of human life. The review focused on soil degradation beyond global pandemic, causes, impacts, control and prospects. The work majorly concentrated on developing countries like Nigeria while giving a global view of soil degradation. In this work we attempted to show the critical nature of soil degradation, requiring serious attention like the current global pandemic known as corona virus or covid 19. We show that the causes of soil erosion are associated with the degradation of key physical and chemical soil properties. Notable physical soil property reductions are caused by water and wind erosion, including surface crust formation, and the chemical soil property reductions are associated with soil fertility decline, salinization, sodification, and other processes. Each cause of soil degradation may be traced to land management. This review notes that addressing soil degradation is important to meeting the 2015 United Nation sustainable development goals.

**Keywords:** soil degradation, erosion, agronomic measures, global pandemic, covid 19

## 1. Introduction

Covid-19, a novel, fast moving global pandemic [1] caused by the Severe acute respiratory Syndrome Corona virus-2 (SARS-Cov-2 virus) [2] Which has engulfed the world since 2019 has recorded over 3,117,542 deaths as of week 16 2021 [3]. A disease that was noticed in Wuhan China firstly and later reported to World Health Organization (WHO) on 31st December 2019, sinking major World economies with major impact on health, Aviation, agriculture, hospitality, education, sports, oil and gas [4, 5] almost all sectors of life. Since the outbreak, a lot of awareness have been

created drawing the attention of humanity to it. Due to the nature of the disease, countries of the world have committed fortune to the tune of over USD 11.7 trillion [6] see to its eradication yet the disease is worsening.

Beyond covid-19 pandemic is an environmental issue of major concern to all nations of the world known as soil degradation: a major and most prominent subset of land degradation. The global spread (**Figure 1**) threatens the sustainability of human life [7].

By 2050, 50–700 million people worldwide are likely to be forced to migrate due to a combination of climate change and land degradation [8]. Soil, one of the world's limited, nonrenewable resources takes between 200 and 1000 years to form 2.5 cm of its top [9]. Word wide eroded soil up to the tune of 50 billion tons each year costs up to US$150 billion (US$3 per ton), nutrient loss in eroded soil costs US$100 billion per ton and offsite impacts cost US$400 billion per tons [9]. Apart from the above mentioned, European Commission documented that the process of soil degradation can lead to collapse of ecosystem and landscape structures such as those of **Figures 2–5** making societies more vulnerable to extreme weather conditions, risks political instability and food insecurity.

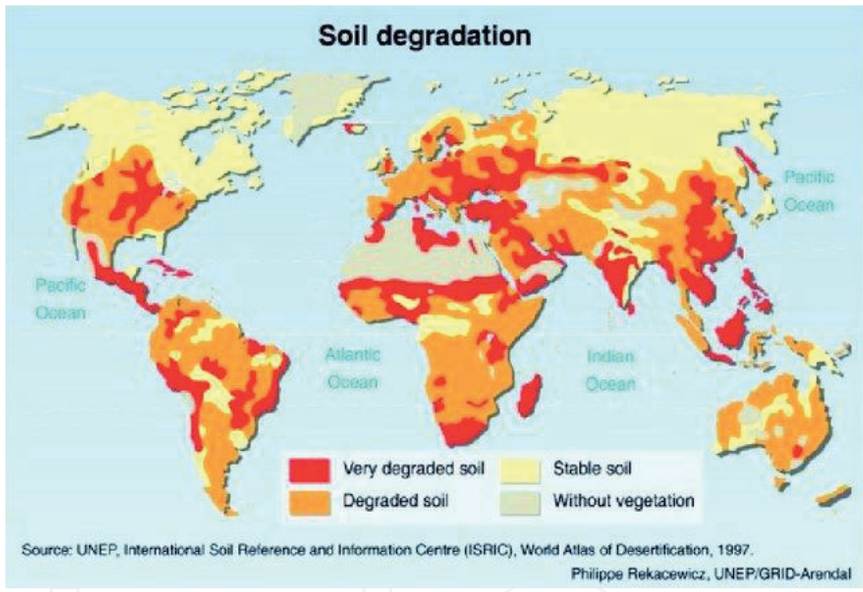


**Figure 1.**
*Global distribution of soil degradation.*

**Figure 2.**
*People risking abandoning their homes to erosion.*

**Figure 3.**
*Road cut as a result of soil degradation.*

**Figure 4.**
*Active gully site in Owerri Imo State.*

**Figure 5.**
*Agro forestry. Source: [52].*

To fulfill the food demand of the increasing human population especially in developing countries most of whom living terrifyingly close to poverty line, greater attention must be paid to sustainability of arable land usage [11], which must have to increase by 13% or 120 million by 2030 [12]. The associated crises affecting the quality of human diet, shifting attention to highly processed foods with less available fresh vegetables and fruits could create health challenge vicious cycles thus making a fertile ground for covid 19 and other related health issues to thrive. European Commission [8] documents "Caring for Soil is Caring for Life" stipulated that 75 % of the world's soils ought to be sound/healthy for food, people, nature and climate and doing so, will help to achieve the UN 2015 sustainable development

goal no. 15: Life on Land. Food production is a factor of soil quality, therefore, the restoration of soil quality and functionality strengthens the resilient of soil for food production and environmental friendliness.

## 2. Soil degradation: definition

Soil degradation is the temporary or permanent diminution or lowering of the productive potential of soil of an area to perform ecosystem functions [13]. A soil is degraded when one or more combination of human induced processes acting upon it affects its biophysical value [14]. Eswaran et al. [15] defined soil degradation as any recognized deleterious, detrimental, undesirable destructive disturbance of the soil. The Global Assessment of Soil Degradation (GLASOD) opined that soil degradation caused by humans deteriorates soil quality imparing partially one or more of its functions [16].

Soil degradation sets in when the capacity of an ecosystem to renew itself is constrained by disturbances [17]. The degradation of soil, traces back to the Neolithic time between 7500 and 10,000 years ago as inappropriate agriculture practices were embraced by mankind [18] and linked also to over population [19] and land use [20]. It takes several years or decades for soil degradation to be noticed or recognized. This is because the process of degradation is gradual and when it has occurred, it takes a long time to fully reclaim the soil. Soil degradation is the most prominent subset of land degradation. This is on the ground that it is the most manipulated feature of land. Studies of land degradation are mostly approached from soil degradation point of view [21]. Other factors that contribute to land degradation include, water and forest respectively.

UNEP [22] rated the severity or intensity of erosion in an area as (a) Light: where the landscape has low potential to sustain agriculture and management modifications can restore its productiveness. (b) Moderate: The soil here has a greatly reduced productivity, but is still suitable for use in local agricultural activities, major improvements are required to restore the soil) (c). Strong: Here the productive potential of the soil is virtually lost and the farm becomes unsuitable for agric activities. To rehabilitate the soil in this category requires major engineering works/investments are required to rehabilitate the landscape. (d) Extreme: The environment here is irreclaimable and efforts to restore it will be in futility.

### 2.1 Processes/forms of soil degradation

Several researchers have recorded several causes of soil degradation. Brady and Weil [17] outlined water erosion, wind erosion, chemical degradation and physical degradation. Mbagwu et al. [23] added soil fertility decline, salinization, water logging and lowering of water table. The major causes of soil degradation include human activities [24], over grazing, deforestation in appropriate farming practices, deforestation leading to desertification, wild fire, road construction; accelerated erosion by water and wind [25], natural factors, over exploitation of vegetation for domestic use and bio industrial activities [22]. Ofomata, and Igwe et al. [26, 27] showed that the environmental factors of vegetation, geology, geomorphology, climate in the form of rainfall which is very aggressive in the tropics and soil factors all contributed to soil degradation problem and its development.

#### *2.1.1 Water and wind erosion*

Water erosion is the detachment, (releasing of soil particles by the action of direct rainfall) transportation (splashing, floating, rolling and dragging of detached

soil particles) and deposition of transported soil particles at certain places of lower elevation by water [28]. Whereas the mechanics of wind erosion are saltation (short skips of detached soil particles, suspension (rolling extending upward to a distance), surface creep (rolling or sliding of particles) by wind.

Soil erosion could be accelerated or natural [17]. The accelerated form of it, is human induced, as a result of farming on marginal land, construction deforestation etc. whereas the geological (natural or normal) erosion is the inexorable and continuous process of evolution of the earth's surface by such geological agents as rainfall, overland flow etc.

Occurrence of soil erosion in fields could be rated or assessed based on incorporation of the loss of top soil and landscape deformation through gulling, riling etc. as follows; Slight: where the top soil has been removed and whose crop rooting depth is exceeding 50 cm, moderate: here all top soils have been removed and formation of gully sets in), Strong (in this rate, all top soils here must have been removed, moderately deep gullies up to 20 m apart are seen) and finally Extreme(Here land is irreclaimable and impossible to restore) [29].

### *2.1.2 Forms of water erosion*

Water erosion comes in the following forms: Splash erosion: the impact of raindrops may liberate particles from the soil surface. On slopes, it contributes to the general movement of loosen particles by flow or wash processes.

Sheetwash or inter rill erosion: occurs as a continuous film of water when the ground surface is smooth or as a myriad of small interconnected rivulets on rougher surfaces. Sheetwash is effective in eroding particles loosened by both drop impact and the progressive increase in soil water content that occurs during a rainfall event [30].

Rifling: results from the concentration of overland flow [31]. The depth of water in rills is greater and more turbulent than in sheet wash, giving the potential for larger particles to be entrained. Rills develop into networks that can, over time, extend laterally and up slope. However, they can be removed by plowing and need not be an obstacle to agriculture, though they will reappear unless remedial action is taken to deal with their cause.

Gullying: can result from the widening and deepening of rills, or by a change in surface conditions on a slope leading to a sudden increase in runoff [32] A gully can be defined as having a steep head and sides, wider than 0.3 m and deeper than 0.6 m. Gully development can be rapid and not only do gullies act as effective conduits for the removal of soil from fields, they obstruct movement and inhibit the use of mechanized farming methods.

Piping: is erosion through the development of subsurface tunnels. This can occur naturally, particularly in dispersive soils or those subject to marked action by burrowing animals [33], but it is enhanced by a reduction in surface vegetation and a loss of internal binding by roots.

### *2.1.3 Methods of predicting the extent water erosion*

Over the years, methods of measuring soil erosion such as estimation of rates of sediment transport in rivers, calculation by the use of empirical formular for a given soil type and slope [34] exist. Others include, Rational method, Unit hydrograph, hydrologic basin [35], air photo interpretation, (API), geographic information system [36], rain fall simulation methods [28]. Each of the above has their associated limitations. Apart from these, direct and indirect methods of assessing soil erosion have been established. De Vleeschauwer et al. [37] compared various detachability

indices for a range of soil in Nigeria. Lugo-Lopez et al. [38] predicted the erosiveness of some soil from Puerto Rico by an index that involved dispersion ratio and soil moisture equivalent. Agim [28] determined sediment yield and runoff through rainfall simulation methods in selected soils of Southeastern Nigeria. Though these methods abound, the need for more precise ways of predicting soil erosion led to the development of more acceptable methods known as the Universal Soil Loss Equation (USLE) Wischmeier and Smith [38] which states that amount of soil loss (A) is a function of erosivity (R), erodibility (k), slope length and steepness (LS), management cover and support practices (CP) (A= R.K.LS.CP). The limitation in USLE ((i) The empirical nature of it in computing soil loss does not show the actual soil loss in theory. (ii) Prediction of average soil loss thereby computing less values when measured. (iii) It does not compute gully erosion but sheet and rill erosion (iv) Does not compute sediment deposition which is higher at the point of deposition than when it is detached) also led to the development of Revised Universal Soil Loss Equation (RUSLE) and later Water Erosion Prediction Project (WEPP) developed by Agricultural Research Service and the USDA National Soil Erosion Research Laboratory.

The RUSLE which is land use dependent took care of the values of erosion s modified by vegetative cover with improved calculation of slope length. It gave better account of runoff water that is capable of being channeled into rills and gullies than being uniform as posited by USLE. Converging, diverging terrains, areas with rock fragmentation are also taken care of than in USLE. On its own, the water erosion prediction project (WEPP) which is physically based in erosion computation model, can assess a variety of landuse and climate. It integrates plant science, hydraulic mechanics to predicting soil erosion at hill tops and watershed scales. In Nigeria, [26] used multiple regression model to successfully predict erosion. Igwe [40] predicted erosion with water dispersible clay indices.

### 2.2 Compaction, sealing and crusting

Compaction, sealing and crusting of topsoil, and water logging are classified as physical processes of soil degradation [22]. Soil compaction, is brought about by the utilization of large equipment and stomping on by animals on soils with a low primary dependability while crusting and sealing are due to the obstructing/sealing of the soil pores by fine grain silt and clay particles dispersed by raindrop impact [41]. Animals stomping or stamping on the soil can also prompt soil crusting. They hinder the tillage of arable soils, and impede or delay the emergence of seedlings and the penetration of roots; they adversely affect soil diversity of soil microorganisms. Nutrient cycles can be altered resulting to a decrease in nutrient levels in soil [42]. Soil water infiltration capacity is also diminished; affecting soil moisture properties and causing increased surface runoff and often higher erosion. Water logging includes submergence by rain water and flooding by river water caused by interferences on natural drainage systems by man. It results when rain water is applied in excess of the needs of the crops than the soil infiltration capacity. This leads to the severe loss of soil air content causing stress to plants as a result shortage of oxygen. In these conditions plants are stressed due to a shortage of oxygen for metabolism by the roots, micro-organisms responsible for biodegradation of organic material are inhibited or killed. Water logging also causes problems of salinization.

The physical consequence of salinization, is sodication which is one of the chemical degradation process. It occurs by the dominance of sodium ions in the soil as a result of concentration of water by evapo transpiration. Sodication results to structureless soil which is unfavorable to root development, almost impermeable to water.

| S/No. | State | No. of gully sites | Stages of development | level of control |
|---|---|---|---|---|
| 1 | Abia | 300 | Some dominant/some active | No records |
| | Ebonyi | 250 | Stages of development | Level of control |
| 2 | Imo | 450 | some active/some dormant | Not successful |
| 4 | Enugu | 600 | some active/some dormant | None |
| 5 | Anambra | 700 | mostly active | Not successful |

*Source: [28, 49].*

**Table 1.**
*Severity of gully erosion under different stages of development in southeastern Nigeria.*

Aridification is the change in soil moisture content for a more water-deficient soil system that is brought about by human action. It is mostly seen in areas where lake or River is used for agriculture.

Subsidence of organic soils according to Doornkamp [43], is the subsidence of organic soils occurs when peaty materials become susceptible to oxidation after drainage has lowered the water table, leaving the peat susceptible to oxidation and deflation, hence lowering the land in a similar manner to the way in which clay soils shrink when desiccated.

### 2.3 General impacts of soil degradation

Soil degradation has been quoted by [44] to be a serious threat to man especially in developing countries of the world notably West Africa [45] where about 65% of the land is classified as being degraded [46]. The environmental and economic impact and of soil degradation have been grouped into onsite and offsite effects [17]. Onsite effects include physical removal or loss of nutrient rich top soil [47]. There is well over $26.5 \times 10^9$ metric tons $yr.^{-1}$ global soil loss of top soil a factor that increased diseases such as ebola and Marbug virus and reduced GDO by 10% [4]. Loss of nutrient rich top soil causes decline or low crop yields and accounted for less than 1.5 t $ha^{-1}$ beyond 5 $tha^{-1}$ yield potential of cereal crops over the past five decades in sub Saharan Africa [48]. Wide spread gullies like those in the **Table 1** have separated communities (**Figure 2**), forced people out of their homes and destroyed construction works (**Figure 3**), abandoning of arable lands (**Figure 4**). There has been increased in tree lodging, windblown dust leading to health hazards from wind erosion. On the other hand, offsite effects include increased cost of production. In this connection, about US$68bn per year is lost to Soil degradation, a value that reduces the regional annual agricultural GDP by 3% [50]Beyond the loss of fertile land [14], the effects of soil erosion extend to high pollution and sedimentation in streams and rivers, a major cause of euthrophication, turbidity of Rivers and which causes declines in fish and other species.

## 3. Control

The rate of soil degradation, and the possibility of its control, depend on the type of process involved in the degradation [16] Since rainfall and wind are the major drivers of water and wind erosion, efforts geared to erosion control should target those that will stop/reduce the direct impact of rainfall, improve infiltration rate, reduce runoff, build organic matter thereby restoring soil fertility. These factors are grouped into three namely agronomic, biological and engineering measures [51]. Agronomic measure targets the use of dead or fresh vegetation to shield soil surface

from direct raindrop impact and to establish rough surfaces that will impede reduce runoff [52]. The agronomic technologies also help in water conservation and have being adjudged as a key adaptation strategy for developing countries of world, especially in sub-Saharan Africa [10].

## 4. Examples of such measures include

### 4.1 Agro forestry practice

This involves the planting of different trees and shrubs grown together with different agricultural crops, pasture and life stock (**Figure 5**). In this system there is ecosystem interactions that help to build up the resilient of the soil.

### 4.2 Conservation tillage

This is the type of tillage that requires no tilling but involves the leaving of previous crop residues on the soil. This also helps in carbon sequestration. Conservation tillage has zero tillage, minimum tillage, permanent soil cover, crop rotation and section as the available types (**Figure 6**).

### 4.3 Mixed/intercropping

According to [53, 54] mixed cropping/Intercropping is when two or more crops for instance cereals and legumes are planted at the same time in the same farm

**Figure 6.**
*Conservation tillage. Source: [52].*

**Figure 7.**
*Mixed/intercropping.*

**Figure 8.**
*Strip cropping. Source: [52].*

(**Figure 7**). For and intercrop to exist, the level of temporal and spatial overlap between the two crops must somewhat vary. Notable examples include row cropping where crops are alternately arranged in rows, temporal intercropping where slow growing crops are grown sown with fast-growing crops such that the later can be harvested before the later.

### 4.4 Strip cropping

In this type of agronomic method, crops are planted in narrow strips across a land slope. Arrangement here is that the strips are placed in such a manner that the strip crops are separated by close growing crops that are erosion resistant (**Figure 8**).

| Geologic formation | Organic amendment | Rates of amendment application on sediment yield (kg $m^{-2}$ $hr.^{-1}$) | | | Rates of amendment application on runoff (mm) | | |
|---|---|---|---|---|---|---|---|
| | | 0 t $ha^{-1}$ | 10 t $ha^{-1}$ | 20 t $ha^{-1}$ | 0 t $ha^{-1}$ | 10 t $ha^{-1}$ | 20 t $ha^{-1}$ |
| ARG (Ishiagu) | Goat dropping | 3.72 | 3.24 | 3.06 | 125.30 | 111.30 | 119.70 |
| | Poultry dropping | 3.72 | 3.57 | 3.09 | 125.30 | 118.00 | 104.00 |
| CPS (Obinze) | Goat dropping | 2.72 | 1.18 | 1.39 | 95.90 | 95.20 | 89.00 |
| | Poultry dropping | 2.72 | 2.56 | 2.07 | 95.90 | 81.50 | 70.90 |
| FBS (Umulolo) | Goat dropping | 1.66 | 1.71 | 2.16 | 87.50 | 85.30 | 80.80 |
| | Poultry dropping | 1.66 | 2.18 | 1.75 | 87.50 | 85.00 | 81.50 |
| BAG (Bende) | Goat dropping | 3.95 | 0.28 | 0.20 | 91.90 | 86.10 | 85.00 |
| | Poultry dropping | 3.95 | 2.09 | 1.34 | 91.90 | 78.00 | 63.00 |

*ARG = Asu River group, CPS = Coastal Plain sand, FBS = Falsebedded Sandstone, and BAG = Bende Ameki Group.*

**Table 2.**
*Effects of organic manure on sediment yield and runoff of selected soils under different geologic formation in southeastern Nigeria.*

In strip cropping, runoff water infiltrate into the soil more [51] and at such erosion is reduced.

Other methods include mulching which helps to improve soil moisture and smoothers weed, green manures application, early planting method, building of Man-made terraces and Contour plowing, reforestation (UN 2015 opined to stop degradation, we must preserve forests, deserts and mountain ecosystems).

## 5. Protecting the soil by planting windbreaks

Windbreaks are trees or shrubs directly planted in linear or row form with an intent of reducing the speed of wind, improve the yield of crop and protect livestock from heat and cold. They have the ability of reducing wind speed for an approximate distance of 15 times the height of the tallest tree. Wind breakers also contribute to land scape beautification.

Application of organic manure in the soil [28] showed promising results in the reduction of runoff and sediment yield in selected soils of South Eastern Nigeria **Table 2**.

The organic amendments helped in building soil organic matter that encouraged binding of the soil. This increased the infiltration capacity of the soil.

## 6. Prospects

Looking forward for brighter future, cleaner and bluer environment, awareness creation in schools, increase in soil literacy, soil health training especially in sub Saharan Africa, sustainable government policies can help curb the menace of soil degradation. The above prospects have the potential to contribute to major initiatives for reducing soil sealing, crusting, compaction.

If covid-19 lock down and restrictions between March and April 2020 achieved a lot of challenges facing humanity including lowering atmospheric levels of carbon dioxide [55], the making water of Ganges River drinkable, atmospheric air in rich industrial activity cities made purer, cities bluer than seen in decades [4, 56] significant human depopulation that is capable of creating cooling effects by providing conducive environment [57] which according to [4] the United Nations Climate Change Conference of Parties (COP21) could not solve, reduction in soil degradation could achieve more.

## 7. Conclusion

Beyond global pandemic is soil degradation an issue of global concern that threatens the development of human globally. The concentration of soil degradation in developing countries where poverty level is high calls for urgent action. This work looked at soil degradation from the angles of the causes, impacts, and prospects and proffered some measures for its solution. We identified water erosion, wind erosion, surface sealing together with inappropriate land use practices as some of the major causes of soil degradation. In proffering solutions, we recognized that since water and wind erosion are the major causes, measures to control them should target protection of the soil from direct impact of water and wind erosion, build soil organic matter and increase the infiltration capacity of the soil should be adopted. Notable agronomic measures such as agro-forestry, mulching, strip cropping etc. were recommended. Proffering solutions to soil degradation will go a long way to achieving the UN sustainable goal no 15. Protection of life.

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## Conflict of interest

There is no conflict of interest in this work.

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